

THE ISOTOPIC COMPOSITION OF CARBONATE IN KIMBERLITE, MICA PERIDOTITE AND BASALT ALONG THE 38th PARALLEL LINEAMENT IN KENTUCKY AND VIRGINIA

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The close and intimate association between carbonatites, carbonatitic material, kimberlites, and alkaline rocks poses a number of problems and this study of isotope compositions is an attempt to better understand the genetic relationship and depth of origin of these carbonate-bearing rocks.

A differentiation of the carbonatitic material from the parent magma has been proposed for various mantle originated processes (Hyndman, 1972; Mitchell, 1970). Today there is much debate over the possible types of original compositions of the parent magma. O'Hara (1965) favors a process whereby fractional crystallization enriches the magma in volatiles, etc., to form kimberlite or carbonatite. In other cases, the carbonatite is thought to separate as immiscible liquid globules (Deines, 1970). Some workers (McGetchin and Silver, 1972) have suggested that the low velocity zone may have provided the constituents necessary for the carbonatitic material.

Analyses of fluid inclusions in peridotite minerals suggest that CO_2 is a dominant volatile species in the upper mantle (Roedder, 1965). Green (1972) preferred CO_2 dissolved in crystalline silicates, exsolving to form the fluid inclusions. Recently, Eggler (1976) concluded that at depths of less than 90 km in suboceanic mantle, CO_2 may be present in carbonate minerals (or in vapor, depending upon the geotherm), but cannot be in solution in silicate peridotite minerals. However, beneath the continents he suggests that CO_2 will be present in carbonate minerals, and the mantle will not melt at least to depths of 120 km. Irving and Wyllie (1973) also pointed out that the carbonate minerals in the mantle may be the site of CO_2 .

Because of the abundant carbonate-bearing mafic alkalic igneous rocks including kimberlite and ultramafic intrusives that are distributed along the 38th Parallel Lineament and show a close agreement between the time of movement of the lineament and the time of intrusion, an attempt is undertaken to better understand these relationships (Hunt, 1976).

The spatial distribution of the igneous rocks within a local area is related to segments forming the Lineament but the occurrence of kimberlites of eastern Kentucky, the mica peridotites of western Kentucky, and the basalt of Virginia may be related in terms of an overall structural pattern involving possible ancient plate margins and chemical plumes.

Interpretation of Results

Figure 1 and Table 1 show the carbon and oxygen isotopic compositions of carbonate samples studied of kimberlite, carbonatite, mica peridotite, basalt, alnoite, marine limestone, and altered ore-rich limestone. The isotopic compositions are expressed in the standard delta notation as per mil deviations from the PDB standard for carbon and from the SMOW standard for oxygen.

The variation in isotope values may be due to a number of factors if some assumptions are taken. The dikes of western Kentucky and the kimberlites of eastern Kentucky may form a related petrographic province, in that they appear to have similar ages, are related to the 38th Parallel Lineament, same structural feature, and have similar silica contents. The chemical analyses taken from the literature (Koenig, 1956) for these rocks suggests a standard differentiation trend from a common parental source. The variation in chemical composition shows an increase in K and Na, and iron as a result of differentiation with time. There would be a preference of Mg over Fe in earlier formed minerals, and therefore, Fe becomes concentrated in the late fraction of the melt. If these rocks had a common source, the higher Mg content and lower Fe would represent an earlier and deeper source for the kimberlites of eastern Kentucky than the mica peridotites that are enriched in Fe and poorer in Mg than the kimberlites.

Therefore, the crystallization after differentiation of the primary calcite from the parent source the residual magma would be enriched in O^{18} and expressed in the late forming calcite of the mica peridotite. The main factors such as variations in depth of intrusion, temperature, PH_2O , PCO_2 will have an effect on the isotope ratios at the time of formation of the calcite.

The possibility of calcite as being a weathered product, the result of assimilation of rock fragments, a result of younger thermal solutions cannot be ignored. Even though samples came from drill cores beneath the surface, 270 to 329 feet depths, the carbonate of the Hutson dike represents ore carbonate replacement shown by the unusual isotope ratios. The oxygen isotope ratios in carbonates can be altered by post emplacement exchange with meteoric waters. It is possible to argue for the preservation of the ratios on the basis of observed textures, but in some cases there is evidence of cross-cutting alterations in the form of calcite recrystallization and veining in the Hutson dike.

If the isotope ratios now observed in the rocks do represent the original ones, then it is possible to make some observations about conditions during and after the time the rocks were formed. The igneous rocks of eastern Kentucky are all relatively fresh, showing little or no obvious weathering. There are no subsequent thermal events in the area that would cause metamorphic decarbonation of the carbonates that would lower the isotope ratios in the residual carbonate as observed by Deines (1969) in the Montreal area of Quebec. If the isotope ratios represent changes during magmatic differentiation over a proposed chemical plume, then there may be a common source area of isotopically homogeneous material. The limited data suggests that differences do exist between comagmatic rock types; kimberlite, mica peridotite, and a basaltic dike. These rocks may represent different fractions of a parent magma which differentiates within the mantle, giving rise to a chemical plume (model of Anderson, 1975) followed by plate movement.

Carbon isotope ratios may be used as tracers of depth of origin for a particular tectonic grouping and in conjunction with the oxygen ratios they may be used to determine the effects of post-magmatic exchange. The calcite of the western Kentucky dikes and the eastern Kentucky kimberlites occurs as medium to fine-grained aggregates which is interpreted to be a late magmatic crystallizing mineral, but in some cases the calcite phenocrysts of the western Kentucky dikes is interpreted to be the original mineral composition formed at depths of about 90 to 120 km.

TABLE 1: Isotopic compositions of carbonate samples studied of kimberlite, limestone, carbonatite, mica peridotite, and basalt

Sample localities	Description (%)	C ¹³ PDB	O ¹⁸ SMOW
EL-100 Kimberlite from locality 1 Elliott County	14 calcite, 23 opa., 7 rock frag., 41 olivine, 12 serp.	-4.6	+11.6
EL-200 Kimberlite from locality 2 Elliott County	12 calcite, 22 opa., 2 rock frag., 45 olivine, 17 serp.	-3.7	+18.2
EL-304 Kimberlite from locality 3 Elliott County	9 calcite, 12 opa., 14 rock frag., 37 olivine, 21 serp.	-6.0	+14.2
EL-302 Rock frag. in kimberlite	27 calcite, 63 fine grain. (serp?) unidentified	-6.1	+15.9
NW-Y-71 Newman Ls. Stop 10 KGS conf. Grayson, Ky	62 calcite, 35 clay, 3 qtz.	-1.6	+21.5
EL-207 Limestone from locality 2 Elliott County	38 calcite, 60 clay	-0.3	+23.2
S-6c Carbonatite Oka Complex, Que.	90 calcite, 5 apatite, pyroxene, 5 biotite	-5.7	+4.1
Ark -K2 Carbonatite, Kimsey Quarry, Ark.	all calcite	-5.6	+5.8
HT-1 Hutson Dike Livingston County, Kentucky	57 calcite, 3 serp., 34 opa., perovskite, 6 mica, apatite, qtz.	+1.4	+27.8
HB-2 Hobby Dike Caldwell County, Kentucky	21 calcite, 41 serp., 23 mica, 7 opa., apatite, 8 sphene, clinozoisite, perovskite	-3.88	+17.95
F-5 Flanary Dike Crittenden County, Kentucky	42 calcite, 24 serp., 19 mica, 14 opa., apatite perovskite	-4.89	+19.68
SC-2 Shell Core Dike, Crittenden County, Kentucky	22 calcite, 38 serp., 27 mica, 11 opa., apatite, 2 clinozoisite, perovskite	-2.90	+19.02
Va-2 Basaltic Dike Highland County, Virginia	9 calcite, opa., 90 bio., plag., pyroxene	-3.3	+21.88

FIGURE 1. PLOT OF O^{18}/O^{16} VERSUS C^{13}/C^{12} 